A NEW SIMPLE SPRING METHOD FOR THREE-DIMENSIONAL UNSTRUCTURED DYNAMIC MESHES

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In this work we consider the problem of deforming unstructured three-dimensional grids. Dynamic meshes are used in many computational applications, including problems with moving boundaries and interfaces, and for r adaption. The most commonly used technique for grid deformation is based on the spring-analogy method, whose basic idea is to create a network of springs connecting all vertices in the grid. In the first and simplest of this class of methods [1], each mesh edge is replaced by a spring, whose stiffness is inversely proportional to the edge length. This way, longer edges will be softer, while shorter ones will be stiffer, somewhat preventing the collision of neighboring vertices.

While this classical method works well in a number of cases, it is well know that it does indeed fail as soon as the local grid motion is not small compared to the local mesh size, or, more in general, whenever a mesh vertex crosses a neighboring face. Unfortunately, in many practical cases the necessary grid displacements are not small, for example when conducting implicit coupled fluid-structure interaction simulations. Furthermore, even if the displacements are small, there is no mechanism in the edge-spring method that prevents the creation of nearly flat elements, which will create ill-conditioning in the PDE solver and will usually induce severe limitations on the allowable time step size.

Methods have been proposed to address this limitation, as for example in ref. [2], where torsional springs are added to the linear edge springs in order to avoid vertex-face crossovers. In this work, we propose a new method that avoids invalid triangulations, while at the same time guarantees good quality elements even for large applied displacements. This method is significantly simpler than the torsional spring method, and is based on the idea of complementing the linear edge springs with linear vertex-face springs. These additional springs effectively constrain each vertex within the polyhedral ball that encloses it, therefore ensuring a final valid mesh. Furthermore, the presence of the additional springs is also beneficial in terms of mesh quality, since they will tend to keep each vertex close to the centroid of the ball, pushing it away from its boundary.

The new proposed method is compared with the edge-spring and torsional spring methods on a number of significative three-dimensional examples.

References

[1] J.T. Batina, “Unsteady Euler Airfoil Solutions Using Unstructured Dynamic Meshes,” AIAA Paper No. 89-0150, AIAA 27th Aerospace Sciences Meeting, Reno, NV, 9–12 January 1989.

[2] C. Degand, C. Farhat, “A Three-Dimensional Torsional Spring Analogy Method for Unstructured Dynamic Meshes,” *Computers and Structures*, v. 80, p. 305–316, 2002.